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Emerging Options and Opportunities in Civilian Aeronautics

Dennis M. Bushnell
Langley Research Center, Hampton, Virginia

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Langley Research Center
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Abstract

Paper address the major problems/issues with civilian aeronautics going forward, the contextual ongoing technology revolutions, the several emerging civilian aeronautical "Big Ideas" and associated enabling technological approaches. The ongoing IT Revolution is increasingly providing, as 5 senses virtual presence/reality becomes available, along with Nano/Molecular Manufacturing, virtual alternatives to Physical transportation for both people and goods. Paper examines the potential options available to aeronautics to maintain and perhaps grow "market share" in the context of this evolving competition. Many of these concepts are not new, but the emerging technology landscape is enhancing their viability and marketability. The concepts vary from the "interesting" to the truly revolutionary and all require considerable research. Paper considers the speed range from personal/general aviation to supersonic transports and technologies from energetics to fabrication.

Introduction

Civilian Aeronautics is currently pursuing a self-fulfilling prophecy, becoming a "mature" commodity Industry. Advancements have been essentially incremental for decades. This incrementalism is in fact "usual" as an industry matures. Aeronautics was a technological "fast-mover" in the mid 20th century with many "players", most of which have merged or gone out of business. New products can be a "bet the company" situation and the industry is currently far more "comfortable" with long technology maturation processes for risk reduction. The industry is based largely upon long haul transport aircraft with an emerging small jet component and legacy general aviation markets and products.

Civilian Aeronautics in the U.S. is at a crucial crossroads. At one time and over an extensive period (from the '20's into the '70's) aeronautics was one of the "IT/Bio/Nano" class technology revolutions of the day with a frontier credo of higher/faster/farther. Aeronautics was deemed to be so critical to the national well-being that it became one of the very few industrial arenas wherein fundamental, advanced and pre-competitive research was supported by the federal government (others include National Defense, pharmaceuticals and agriculture). Many studies exist justifying this special status, as it is, understandably, under continuous scrutiny. Today and into the foreseeable future aeronautics is beset with a wide spectrum of problems which the IT, Nano and other ongoing and nascent technological revolutions will both potentially aggravate these problems and enable truly Revolutionary "solution spaces." This treatise will examine and comment on both the prospective problem and potential solution spectrum/ spaces going forward.

It is interesting to note that many of the various Aeronautical goals addressed in this report are called out in Ref. 59, the 2010 update to the U.S. National Aeronautics R&D plan from the National Science and Technology Council. These include an advanced ATC system enabling UAS in the NAS, increased L/D and innovative Structural Concepts, and decreasing Aeronautical Environmental impacts, among many others. The concepts addressed in the present report, individually and/or combinatorially are in general beyond the current extant Aeronautical R&D approaches.

The Civil Aeronautics "Problems"

<u>Continuing Loss of U.S. Market Share</u> – The world has long changed from the immediate post WW II scenario of U.S. technological dominance. To first order, research is the order of 2% of gross domestic product (GDP) and the U.S. produces the order of 20% (and dropping) of the Worlds' GDP. Therefore, a major [~ 70%] and increasing portion of the Worlds' research is now conducted outside of the U.S. Also, the deployed civilian aeronautical technology tended toward evolutionary (as opposed to revolutionary) by the end of the 1970's and some U.S. competitors have, in some cases, been more aggressive in fielding advanced, evolutionary technologies. Civilian aeronautics, based upon the deployed technology, became more of a mature, commodity industry with many current and potential foreign players. Extensive studies have documented long running reductions in U.S. Market share for transport/other aircraft.

Other factors impacting civilian aeronautics market share include business/technology "globalization" and the secondary effects of the end of the cold war/consequent restructuring of the related military aeronautics industry. The key phrase/issue in all of this is "deployed technology." A related key issue is an unstated but assumed restriction to "the usual markets." Revolutionary technologies and technology related market changes could greatly impact this and all other aeronautical problem areas. This problem is of course exacerbated by the cyclic nature of the industry, and its' importance to U.S. macro-economics as aerospace has historically constituted the largest favorable trade balance in the manufacturing sector.

Increasing Acoustical Strictures – For decades takeoff (primarily propulsion-related) and more recently landing (primarily airframe noise-related) acoustical regulations have modified/restricted both aircraft/engine design and operation. These acoustic regulations tend to change so as to correspond to, and push, the technical state-of-the-art. What the public evidently would really desire is clear – "noiseless" (compared to the nominal "background") aircraft operations. Entire classes of aircraft, notably the supersonic transport (SST), have been literally "taken off the design table" due to acoustic-related issues/strictures. In the National Aeronautics and Space Administration High Speed Research (NASA HSR) program a pound of weight on the HUGE mixer-ejector required to suppress takeoff jet noise corresponded to the order of some 32 pounds of takeoff weight – severely compromising the overall design. As the population has moved outward to engulf airports, many of which were initially located in sparsely populated regions, the Aeronautical noise-related problems/resultant societal "upsetness" has become aggravated. Acoustics is a major reason for the inordinately long (decades in some cases) periods required to construct new airports or carryout major modifications thereof. Some airports have even instituted noise-engendered "curfews" for aircraft operations/schedules.

Increasing Environmental Strictures – After several decades of concerns and warnings global warming appears to have changed from a theoretical possibility to a measurable reality. Societal response is becoming decreasingly one of denial but major societal and technological changes have not yet been instituted, due primarily to

their overarching impacts upon life-styles and economics. Society as a whole is obviously still in "denial" regarding what needs to be done, both in terms of regulatory strictures and whole new classes of technologies. However, this state of denial (driven by the inexorable laws of physics, chemistry and thermodynamics) will change at some point into action; actions which will affect aeronautics as well as every other energy utilization industry and activity. Currently aviation is studying ways and means to reduce Carbon Dioxide (CO_2) and Nitrogen Oxides (NOx), including use of biofuels as well as aircraft efficiency. However, scientific studies indicate that an additional potentially significant "warming" problem involving aeronautics operations may be the deposition of water vapor (yet another result of the open cycle combustion of Hydrocarbons) above ~27,000 feet [The Tropopause], leading to the formation of extensive Cirrus clouds and further changes in the Earth's Albedo/"warming." The ultimate solution to all of this would be to utilize "emissionless" propulsion. Some Nations are already considering the institution of a "carbon tax," which would, as a minimum, increase the costs of aircraft operation.

Aging/Aged Air Traffic Control System – The problems with the air traffic control (ATC) system are at this point infamous. Estimates of the cost to the U.S. economy of airport/airspace congestion are in the billions. In one month there were purportedly some 100 major problems in/with the system. There are clarion calls, and current on-going studies to "fix" the system. An additional major/paradigm-changing requirement is the increasing necessity to accommodate military, DHS (and later civilian) automatic-to-autonomous air vehicles [AKA UAS] in "controlled" air space. Congress is pushing hard, for a myriad of very valid reasons, to have a major portion of military air vehicles 'uninhabited" and military planning is also working in this direction. The current ATC system is highly labor intensive and therefore costly.

Aviation Security – The infamous 9/11 incident involving the high-jacking and subsequent use as cruise missiles of commercial aircraft along with the overall suite of potential aviation-related terrorist threats have greatly increased concern regarding aeronautical security. What is ultimately required is far more than merely keeping "bad people and bad things" off of aircraft—although this is an obvious place

to start working the problem. An emerging "security" problem is electro-magnetic pulse [EMP]. Flux compression generators powered by explosives or capacitors are increasingly capable of interfering-to-obviating installed electronics. Such devices could be either delivered by missile or activated on the ground during landing/ takeoff. Fear of being involved in security incidents along with the consequent increase in security-related passenger "hassle-factor" at airports have contributed to some of the traveling public, both business and private, finding other methods of either traveling or conducting their business. Much of airline operations involve relatively short (less than 500 miles) trips, and people are using surface transport more often for these short stage lengths. Also, the increasing capabilities of various forms of electronic communications have enabled substitution of virtual for physical travel in an increasing number of cases. The author recently gave a presentation in New Zealand virtually as opposed to the many days and dollars associated with transpac physical travel/ presentation. Virtual/Tele-Living writ large [commuting/working, shopping, travel, education, commerce etc.] appears to be one of the reasons for the decline in U.S. vehicle miles traveled on the roads. Some are asking whether the U.S. has reached "peak car".

Aviation Safety – This problem area actually has an excellent outlook. Some 80% or so of aviation safety problems involve human actions in some form, including "controlled flight into terrain"– aka, flying into the ground. The overall accident rate/hull loss statistics are much lower than other forms of transportation – automobiles for example, and there are a myriad of relatively straight-forward technology "fixes" in the works to drive the accident rates even lower. Ultimately, the major trends (enabled by the IT/Nano technology revolutions) toward automatic/robotic operation and automatic health monitoring should decrease the "human-related" causes of accidents by getting the humans out of the loop. In fact, "getting the humans out" as a general approach should also result in increasingly major cost reductions as people-related expenses are a major portion of direct operating costs and "electron-related" systems and robotics are rapidly becoming smaller/cheaper/smarter/lighter as well as increasingly reliable.

Radiation – There are two major sources of radiation incident upon the Earth, galactic cosmic radiation and solar engendered. This radiation is

modified by the geomagnetic field and the Earth's atmosphere. As an example, purportedly the ambient radiation at cruise altitude for conventional long haul transports is some 100 times normal ground background levels. The Radiation of concern for aircraft crew and passengers peaks at around 60,000 feet, the nominal cruise altitude for SST's. Airline crew are now classified as "radiation workers" and tend to accrue higher doses than nuclear power plant workers. A rule-of-thumb is that a 4,000 mile flight is the order of a chest X-ray (each way). This is, however, evidently not a major worry for usual passenger travel as the overall percentage of time spent in the air is not large. The safest place radiation-wise to sit appears to be on the aisle in the economy section where the other water-filled humans tend to absorb some of the radiation before it reaches you. The current structural materials such as aluminum tend to increase the levels inside the cabin due to interaction with the incident radiation / production of secondary radiation.. The main risk is to the crew due to their many hours at cruise altitudes.

Increasingly Serious (Non-Aeronautical) Competition – There have been several suggestions over the years that various forms of communication could-to-would provide viable alternatives to physical travel. A study in the mid-nineties by the Transportation Research Board suggested that by 2015 this could cause a loss of some 40% of the (profit-producing) business travelers. There has been some observable trends in this direction but nothing major thus far. However, the available virtual competition (to this point) has usually been restricted to flat screens and a combination of sight and sound. As the huge bandwidth increases of optical communications become very widely available other, far more immersive, non-physical "travel" will become available – virtual reality and holographic projection, either synchronous or asynchronous. Haptic touch has been demonstrated across the Atlantic and a virtual smell approach has been patented. 5 senses virtual reality has been commercially demonstrated. Increasingly time is the critical parameter, and "saving" time is goodness. Increasingly this is not a subsonic vs. supersonic transport issue - this is a physical transport vs. the speed of light/ virtual presence issue. As immersive presence experience becomes "really good and complete" it will often "win out" for time as well as cost saving reasons.

Exclusivity of General Aviation – The "airplane in every garage" and various flavors of personal combined fly/drive machines envisaged over the years never became feasible for a number of reasons including an absolute requirement for an "operator-pilot." There are relatively few within the general population who have the time, health and treasure to become pilots. Therefore, the market never became large enough to accrue the additional factor of 8 or so cost reduction from "mass/quantity production." General aviation (private and business), which accounts for, by far, most of the airports and aircraft in terms of numbers has remained a "rich man's toy" requiring resources in excess of those available to the general population. The nascent "personal aircraft" market is HUGE, with estimates ranging up to $1T/year Worldwide – far larger than the current transport aircraft markets in the U.S. A market which could, if successfully attained, revolutionize societal life styles, land use, national-to-international economics as well as, on the way, "fix aeronautics." Such personal aircraft, particularly if of the fly/drive/ short take off and landing (VSTOL) genre with reasonable (300+ knots) capability would, for many reasons, provide serious competition to domestic commercial airline transportation – the "PC" version of aviation vs. the current "mainframe" (commercial transport) paradigm, as well as competition and infrastructure cost avoidance wrt the automobile market.

Declining Business Case – The civilian aeronautics profit margins are notoriously small-to-negative. This situation could worsen as solutions are sought to many of the problem areas cited herein within the context of the current deployed evolutionary technology suites. Additionally, there are exquisite sensitivities, engendered by the slim profit margins, to various mutable costs of doing business such as fuel price. A major reason for the current business state is the asymptotic/"mature" nature of the deployed technology. The gains in aircraft performance over the past decades, especially in terms of fuel efficiency and noise reduction, are mainly a result of increased engine bypass ratio. Aerodynamic performance improvements have been minimal. Serious attempts to improve aerodynamics via laminar flow control encountered affordability difficulties. Therefore, there is little current or foreseeable "design margin" (with the current deployed technology suite) which would evidently allow the industry to holistically, across the spectrum of problem areas discussed herein "get well" and successfully compete

with the emerging tele/virtual travel alternatives. The cost comparison between these two options is highly unfavorable to aeronautics and the emerging technologies are expected to provide seriously capable virtual presence. The newer generation grew up on /using electrons/ electronics, are already entering the 'Virtual Age".

There has been a reduction in short haul aviation traffic which may be due to one or [probably] several of the following:

- Driving is cheaper
- Increased Virtual/tele-travel utilization
- The Economic downturn
- The actual total effective trip time, with the necessity to arrive early at the terminal and rent cars etc. upon arrival at an airport can be less driving vice flying
- Changes in airline service schedules/ availability

The Emerging Technological Landscape

We are currently in the midst of a major wide spectrum Technological Revolution including IT, Bio, Nano, Energetics and Quantum Technologies. These technologies are altering in real time the entire panoply of human activities, including Aeronautics. The purpose of this report is to consider the potential implications of these rapid technology changes upon both Aeronautical Functionalities/ Markets and the detailed manner in which we execute/realize those functionalities [e.g. both what aeronautics does in the future and how it does it].

IT - We have improved computing, on silicon, some 7 to 8 orders of magnitude since '59, the ~ 15 petaflop human brain speed machine was delivered in 2012. Going forward we will go beyond silicon to bio, optical, nano, molecular and atomic computing with estimates of some 8 to 12 orders of magnitude still to be realized over the next decades. Then there is Quantum Computing, which for an increasing number of applications is projected to provide up to 44 orders of magnitude improvement and is envisaged by some to be less than 2 decades in the future. Thus far in the discussion this is just raw speed. Machine Intelligence approaching human level is being worked via Soft Computing [neural nets, fuzzy logic, genetic algorithms etc], Biomimmetics and perhaps Emergence, the latter is the probable manner by which humans developed "Intelligence" - make something

complex enough and it "wakes up". Presently Biomimmetics, nanosectioning the brain and replicating it in silicon, appears to be the foremost approach, with the IBM Blue Brain Project suggesting human level or nearly so machines at some 10-15 years out. In the runup Machine Intelligence is becoming increasingly "useful"/ capable.

These massive improvements in IT capability are changing society greatly, enabling increasingly "Tele-everything" – Tele commuting/work, shopping, travel, education, medicine, commerce, politics, socialization, etc…. This rapidly developing machine capability has produced a decades long shift in Aeronautical testing/ product development from major dependence upon wind tunnels to increasing dependence upon Mod-Sim / computation. If/when Quantum computing is developed the resulting machine capacity would probably enable ab-initio computation of turbulence in a design mode, resulting in further major reductions in Wind Tunnel requirements. The tele-travel estimates have long projected a major drop in aircraft business travel in favor of tele-travel in less than a decade. This tele-travel would be accomplished via the increasingly capable, initial versions demonstrated, 5 senses virtual reality, haptic taste, touch, smell, sight and sound. Estimates indicate that many millions worldwide are spending now, on flat screens, more time in virtual worlds than in the "real world". This is expected to greatly increase as first virtual reality and then 5 senses virtual reality become available with serious fidelity. From this discussion – possibly fewer airline travelers rather than the large increases in numbers previously projected. Ridership is already less than earlier extrapolations, possibly due to a combination of the economic conditions and the improvements in tele-travel.

The evolving IT technologies also proffer the real possibility of a much more capable and far less expensive Air Traffic Control [ATC]/Navigation/Operations system enabling Uninhabited Air Systems [UAS] in controlled airspace for Military, DHS and Civilian use. Such a system could be developed and proven out piecemeal via operation parallel to the existing system with no operational utilization, just experimental studies, until the entire new system is fully vetted. There are emerging technologies potentially capable of providing triply redundant fail safe-safe communications, navigation, sensors and computing, along with the DOD swarm technologies studies. These

technologies include “Atom Optics” [Inertial Navigation Systems with many orders of magnitude improvements], and passive location/navigation using the TV tower signals with many orders of magnitude greater signal amplitude than GPS. Hal Puthoff has a vector/scalar potential approach that could revolutionize communications, and optical free space communications are developing nicely. Then there is the emerging “Global Sensor Grid”, thanks to low energy improved/inexpensive nano and quantum sensors. The projections indicate networking of vast numbers of sensors, producing a “Digital Air Space” some decade plus out. Such a “beyond Next-Gen” ATC etc. system would enable the deployment of both civilian robotic delivery vehicles and UAS carrying passengers, i.e. PAVE or Personal Air Vehicles. Such vehicles could be both affordable and safe, allow Aero to usurp some-to-much of the automobile markets and enable cost avoidance for some of the surface transportation infrastructure. The vehicles for PAVE are under development, a goodly number are given at www. roadabletimes.com. The estimated PAVE worldwide Aero Markets, with parts, is in the range of $1T/ year, far greater than the current civilian Aeronautical level. As PAVE vehicles are envisaged to be autonomously operated they could be utilized by the aged, the infirm, the young and the inebriated. PAVE is the “Personal Computer”version of Aeronautics and has shown great robustness in terms of “market”/ population desirement for nearly a century. We are now quite close to the requisite technologies.

“The Roads to support Autos cost as much as a small war and the casualties are on the same scale”

Arthur C. Clark, 1984

With the availability of appropriate ATC etc. systems, Robotic Delivery vehicles and PAVE the population could expand in terms of land use to a much lower density, adopting at the same time a Toflerian Prosumer status. We have some 200,000 off the [electric] grid homes now and some, an increasing number, are going off ALL the grids [electric, water, sewage, food] as the technology is enabling such and tele-living becomes more pervasive. Simplex estimates indicate, as an example, a factor of up to 50 less overall environmental impact from tele-shopping as opposed to physical shopping. Autonomous /robotic operation of

both vehicles and the ATC system should be both far less expensive and significantly “safer” as some 80% of aviation accidents are ascribed to “Human Error”.

IT also, via Mod-Sim, enables design of ultra efficient Aero Configurations at R&D costs far less than the Industrial Age methods involving significant physical testing. A current near best bet transport concept appears to be externally truss-braced wings enabling thinner wings and reduced wing sweep for natural laminar flow and greatly increased span for decimation of drag-due-to-lift. If the engines are placed at the rear of the fuselage and thrust vectored for control then the empannage weight and drag can be obviated. Additionally a Goldschmied Cowl around the engine proffers the possibility of favorable propulsive/ airframe interference and provides internal volume for noise treatments. Then there is fuselage [re] laminarization. The lift to drag ratio of such a transport design is in the 40’s plus [Pfenninger designed one with lift-to-drag ratio [L/D] ~ 100] with major [perhaps as much as 80%+] fuel burn reductions. Mod-Sim also would enable Channel wings with circulation control, an interesting super short takeoff and landing approach. An alternative configuration approach having “Sky Train”/ “Modular Aircraft” functionality is a double fuselage/ mid [unswept] Natural Laminar Flow wing concept with the wing tip fuselages optimized for drag-due-to-lift reduction including the engines positioned at the rear of the fuselage[s]. Fuselages are “interchangeable” for optimized operation tempo/ overall system efficiency. Mod-Sim would also enable serious study of a Transonic Bi-Plane, with a tentative performance improvement greater than 25%. For Super short takeoff and landing capability Mod-Sim enables synergistic design of a Channel wing with Circulation control – providing a near theoretical 4 Pi optimal lift coefficient. The massive supersonic transport improvements from the Pfenninger strut braced extreme arrow wing design, with L/D values of order 16 vice 9 ish for conventional configurations are also now within reach courtesy of Mod-Sim, as are favorable wave interference supersonic designs [again order of 25%ish improvements], wave rotors for major overall improvements in GTEs and ring wings of various flavors.

Sir James Lighthill once told the author “We build what we can compute” and this constrained us for far too long to nearly linear

theories and consequent linear thinking/ conceptualization. The IT engendered Mod-Sim has opened up the configuration design spaces to include “open Thermodynamic systems” where the propulsive and aerodynamic functions are synergistically combined, along with such enabling structural concepts as external strut/truss bracing – a further gift of Mod-Sim in terms of interference drag minimization. Pulse detonation wave engines, where the wave dynamics is tailored to provide valving and ignition, along with anti-noise, would enable a much less expensive propulsion device

Nano - Nano materials are projected to have major impacts upon structural weight across the board. These are developing with various “flavors” including Carbon Nano tubes [400 degrees C], Boron Nitride Nano tubes [800 degrees C], Graphene and others. Thus far these have been employed in composite materials but there are efforts underway to produce nano tube structures directly. If successful these might potentially reduce dry weight some factors of 3 to 5 to 8, not percentages, factors , TBD. Then there is the possibility of carbon nanotube springs with estimated performance many orders of magnitude better than steel springs. Applications include Superstol takeoff and landing [employing re-generation], providing an opportunity to “Spring into the air”……

Then there is “strong Nano”, the original Erik Drexler “Engines of Creation” Nano where “Mechanical Engineering” is used to assemble materials “Atom-by-Atom” vice the current largely Chemical Engineering self organizing nano-systems. Such superb manufacturing at the atomic level could possibly enable facsimiles of trabecular bird bones, ultra light structural members, as well as “ageless” materials, bereft of the contaminants, dislocations and inhomogeneities that degrade the strength and usability of current materials. For nearly 2 decades the prevalent opinion was that such strong nano, AKA “Molecular Manufacturing”, was not executable. Recently several groups are making progress and success is expected in due course. IF this “happens” then very localized manufacturing is enabled, e.g. “fab Labs” in the home, and the demand for cargo air transport would probably plummet. In the runup “free form fabrication” by various means including electron beams is increasingly prevalent and increasingly

termed the "Third Industrial Revolution" [The first two were in the 19th and 20th centuries respectively].

Nano also enables a plethora of sensors/ instruments for Integrated Vehicle Health Management [IVHM] and safety as well as "situational awareness" writ large which is enabling for the All Electron/ photon ATC/Nav/Ops system mentioned previously. CNTs are an interesting potential combination of structural material, energy storage material [H2, Electrical], sensor web[s] and even computing as well as actuation. Very advanced batteries enabling serious consideration of electric aircraft of various scales and CNT tethers for high altitude wind energy harvesting are additional potential "gifts" of Nano, as are ice and bug phobic surfaces for safety and laminar flow control optimization.

Energetics - Perhaps the poster child for an Energetics Revolution is LENR, Low Energy Nuclear Reactions. There are now some 20 plus years of worldwide experiments, over a hundred of such, producing heat in excess, often far in excess, of chemical, and various transmutations, with little worrisome radiation and at EV energy inputs not the MEV necessary to surmount the coulomb barrier. There are now several theories for this which indicate weak interactions, not the strong force, are responsible, and there are now many devices worldwide producing many watts to kilowatts whose efficacy we are trying to vett. If this energetics technology proves real and scalable and safe then Aero is changed MUCH. We can then enter into a design space where we have never been before – Energy Rich. Measurements indicate LENR is some 100 plus times chemical energy density with the theory indicating a factor of over 1,000,000. Such energy density with little radiation to worry about enables a Myriad of revolutions in Aero:

- Energy focused far ahead of an SST to reduce Sonic Boom

- SSTs that have little environmental impact, ultra low fuel fraction and are, overall, Affordable.

- Ability to reduce the disk loading, reduce propulsor efficiency to enable Quiet VTOL/STOL operations, i.e. in and out of the street in front of your house in a "neighborly fashion". Overall approach also

applies to reducing transport and SST noise – reduce loading/ efficiency in favor of noise reduction as have a surfeit of energy.

- For anything that flies, greatly reduced fuel fraction/ gross weight, therefore reduced dry weight, huge range increases and massive loiter improvements for climate/ other "sensor craft", "wholly Green"

- Energy for direct control of wake vortices/ vortex hazard and flow control for bird-like/ all weather flight as well as superstol for nearly simultaneous takeoff of several aircraft on the same runway, increasing airport "productivity".

- Design Margins for fail-safe safety engineering, including engine surrounds, effective Faraday cages for EMP protection, 'chutes for large aircraft [or retro-rockets] as well as "crashworthy" aircraft. The many safety issues associated with fuel explosions/ fires "go away".

The estimated costs of energy produced for the Grid via LENR is the order of 25% that of coal, a VERY EARLY DAYS estimate, but indicates positive cost margins wrt petroleum.

In addition, there are emerging sources of biofuels with massive capacity and low cost [~ $50/bbl]. These include Joule Biotechnology approaches, Genomic Cyanobacteria which produce, per their assertion, some 20,000 gals/ Acre-year using CO2, waste water and sunlight. Also, Halophytes, or salt plants [there are some 10,000 of such extant] which grow on wastelands using seawater irrigation. We are running out of fresh water but some 97% of the water is saline and some 44% of the land mass is wastelands. Seawater contains some 80% of the nutrients to grow plants. Estimates indicate that just a goodly portion of the Sahara is capable, via halophytes and seawater irrigation, of producing enough biomass to replace all the fossil carbon fuels, producing the petro-chemical feedstock for the plastics and sufficient food to enable release back to direct human use of some of the 68% of the Fresh water now used for Conventional Agriculture. Halophytes grown on

wastelands irrigated with seawater would "solve" land, water, food, energy and climate.

Both of these advanced Energetics options are "Green", sans net CO2 emissions. The Halophyte/ cyanobacteria sourced fuels would emit CO2 when combusted but with, in the case of Halophytes, better than a closed CO2 cycle due to root sequestration during growth. In the LENR case there are no CO2 emissions and estimates based upon the efficiency of current devices, yet to be validated, suggest that some 1% of the worlds' yearly Nickel production could produce the worlds energy requirements. LENR produces heat, which could be directly used as a combustor replacement or, via such as Pyro-electrics, T-PV or sterling cycles, produce electricity for propulsion. In regard to the other major green house efflux from aviation, water, LENR emits none. Biofuels do emit water and therefore their use requires in general flight below the tropopause [below some 27K ft.] where water efflux is cooling rather than "warming".

Synopsis , Resulting Emerging Technology-enabled Aero Markets and Systems - Given serious research, the rapidly evolving technology revolutions and the large number of tech options to achieve success the following appear to constitute a conceptual laydown of the "Frontiers of the Responsibly Imaginable" in Aeronautics going forward:

- Reduced long haul passenger traffic [due to "Tele-Travel]
- Reduced long haul cargo traffic [due to Molecular Manufacturing and Fab Labs in the runup]
- An economical fail safe-safe totally robotic ATC /Nav/ops system [Digital Airspace] to enable UAS in controlled air space for DOD, DHS and Civilian use
- Robotic Delivery Vehicles
- PAVE vehicles to partially-to-? Replace Autos [~ $1T world wide Aero market]
- Greatly improved Long Haul Transport Performance [via ideation and Mod-Sim]
- SSTS, courtesy of LENRs
- Ultra-long loiter sensor craft for climate/ other studies/ uses
- Greatly reduced Wind Tunnel Utilization [via Mod-Sim-to-quantum computing]

Additional Societal Changes Going Forward that will Impact Aeronautics - In addition to the "Tele-Everything" Societal changes noted herein there are several other simultaneous and significant, mostly human-engendered ,Societal Issues that will impact the aeronautics industry going forward in various ways. The climate positive feedbacks are kicking in [methane hydrates, fossil CO2, reduced Ocean CO2 uptake, increased water vapor, altered albedo etc] making the IPCC climate projections appear to be conservative. There will probably be increasing regulations regarding emissions reductions. The massive debt issues worldwide are projected to increase taxes, inflation and interest rates before they are resolved. For the number of humans extant and the way we are currently living we are apparently short some 40% of a planet, many portions of the Ecosystem are "crashing". As the Asians, at some 9% growth rates , attempt to attain western living standards we are projected to be short some 3 planets. The ecosystem strictures will probably replace the economic growth mantra with sustainability. Also, the increasingly pervasive and capable automatics and robotics are replacing humans in the workplace at increasing rates. Suggest perusal of the Martin Ford book "The Lights in the Tunnel". And, humans are becoming cyborgs, including development of "brain chips". The effects of much of these pressures/ changes will be to reduce standards of living and foster ever greater use of "virtual"/ tele-living writ large. The "Virtual Age" is slated to follow the IT Age and we are rapidly enabling such.

Emerging Aero Configurational "Big Ideas"

Long haul transports have, since the 50's, followed an evolutionary path dedicated to variants of the 707 theme. Various engine arrangements were realized but basically a tubular fuselage and single cantilever wing. The Aero performance for such machines has improved little over that time frame. One method of intuiting potential alternative configurations is to list and obviate the common configurational assumptions. These include such as functional separation of airframe and propulsion, Aerodynamic controls,

horizontal symmetry, high lift/ takeoff capacity built into the aircraft, Etc……Possible obviations include multiple bodies, truss bracing, Multi-stage aircraft, Ski Jumps for takeoff, Thrust vectoring for control, yawed wing[s], Etc……..Over the years a Plethora of configurational "deviations" from the "707" norm have been studied to various levels/ degrees. As an example transonic "Bi-Plane" studies have indicated , using updated technologies, a 60% reduction in wing weight and 30% increase in L/D along with reduced vortex hazard. Thus far this configuration has not been taken up. Ring wings were also studied to some degree and also not taken up. Of the vast panoply of previous configurational concepts, the present report considers some updates to what may be considered the concepts that define various "Frontiers", hence the term "Big Ideas".

Refs. 1-58 and refs. therein provide a robust sampling of the extant Aero Configurational Advanced Concepts literature. What is interesting and concerning is this literature is not far greater and richer and adopted/ applied. The NASA Institute for Advanced Concepts for many years solicited proposals for Advanced Configuration Aero concepts and received only a small number. In recent years NASA engaged industry in ideation of exceedingly advanced aircraft, the "N+3 Studies". These produced concepts with astoundingly large projected/ estimated reductions in fuel burn but the major technology contributions were primarily in propulsion and structures/ materials vice Aero. Boeing did proffer a version of the Truss-braced wing and MIT advanced a unique "double-bubble" lift carrying fuselage with serious propulsion integration. These efforts provide an "existence proof" that configuration Aero still has considerable room for improvement and belies the enduring, since the 50's, reliance on and utilization of the B-47/ 707 configuration Genre. What is perplexing is that an advanced configuration, the BWB, which proffers considerable improvements in performance, has enjoyed serious study now for over 2 decades worldwide, has the B-2 as a flying exemplar, and yet has not been taken up/ deployed. As the various Aeronautical issues/ problems discussed previously herein become yet more acute, this situation should change. Historically such Aero configurational innovation in the U.S. was fostered/ enabled by pioneering Military advances. With the advent of increasingly serious Aero Competition, from Airbus, the Brazilians and the Chinese among others breakthroughs in configuration Aero could well occur outside the U.S.

Truss Braced Wing Et Al - Pfenninger has long advocated strut/truss bracing to improve the performance of conventional transports. The resulting (bending, torsion) structural benefits allow reduced wing weight, thickness and sweep, resulting in a tremendously enhanced and easily maintained (reduced sensitivity to roughness/insect remains/ice clouds, reduced cross flow) extent of natural-to-easily forced low drag laminar flow, along with increased span. The latter allowed a reduction in wing chord, further enhancing the extent of laminar flow, as well as enhanced takeoff and climb performance and reduced vortex hazard. Plenninger's designs for such aircraft yielded L/D values in the 40's, over twice current levels with one of his studies which included a laminar fuselage yielding a machine with L/D = 100, 700 Pax and 200,000 Km range.. The concept was not, however, adopted primarily because the extensive wing span did not fit the FAA "80 meter box" for airport gate compatibility and disbelief that a transonic strut/truss braced wing could be designed with acceptable shock drag (and obtain laminar flow on the strut/truss). Obviously strut-bracing is routinely employed on low(er) speed aircraft. The latter objection is probably not valid in light of today's CFD capabilities. In general, we build what we can compute and we have been too long constrained in aircraft design to linear theory and consequent "linear thinking." Indeed, lack of adequate/believable "first principles" estimation methods for not only performance but cost(s), maintenance/operability, etc. are a major reason why work on advanced aero concepts has lagged. Our current systems methodologies are essentially extrapolation and interpolation procedures based upon, and therefore largely restricted to, empirical data for/from the current paradigms. As discussed, the improved computing machine capabilities/ mod-sim developments are changing such considerations/ judgements in real time.

The span of a truss-braced configuration can probably be doubled and a mid span hinge [already studied in industry] utilized to conform to the 80 meter gate requirement. Doubling span would halve Reynolds Number on the wing and reduce drag Due To Lift the order of 75%. Combining this DDL reduction with the extensive wing Laminar Flow results in most of the remaining vehicle drag being fuselage friction drag. Such drag can be addressed in several ways. The most dramatic is to apply boundary layer relaminarization just downstream of the

cockpit /forward door. The aircraft nose region with the radome, probes, windshield, wipers etc. will be turbulent, therefore need to ingest/ take aboard some 150% plus [to entrain the turbulent "Superlayer"] of the local fuselage turbulent boundary layer and re-establish laminar flow. The increasing use of personal view screens vice windows greatly eases the task of maintaining laminar flow downstream. The air taken aboard can be slot injected into the turbulent wing-fuselage turbulent flow wedge to accrue local skin friction reduction.

The engines can be moved to the rear of the fuselage, surrounded by a Goldschmied shroud. This would enable several interesting/ useful functionalities. The engines could be thrust-vectored, obviating the weight/ drag of the empannage. The shroud provides copious volume for acoustic treatment[s]. The engines ingest the fuselage boundary layer accruing a sizable propulsion improvement. Then there is the oft-mentioned but still under study "Goldschmied Effect" that purportedly could cancel a sizable portion of the fuselage friction drag. The thought is that possibly/ TBD, putting "sinks inside the body" using the cowl could convert the back of the cowl into a stagnation region, thereby producing what Goldschmied called favorable interaction "Static Pressure Thrust".

For long haul transports the weight of the gear is the order of half the fuselage weight. The gear weight could be reduced in several ways. One is to utilize 'chutes instead of super heavy brakes for refused takeoff. Another is to utilize wholly automatic landings with the controls slaved to the altitude/ ground proximity and decent rate to take out the impact loading. Yet another is to employ imbedded hydraulics in the gear structure to provide rigidity only when needed vice carrying the weight throughout the mission. All of these benefits greatly reduce vehicle weight overall, which along with clever vortex flow control can reduce wake vortex hazard.

The conceptual advanced engine technologies mentioned herein could perhaps improve propulsion efficiency the order of 50% [including the aft engine viscous flow ingestion]. Advanced materials on-the-way to eventual development/ invention of structural Nano Tubes, along with the possibility of using inflatable inboard wing sections to enable

further sweep reductions provide weight reductions, including the truss benefits on wing weight, in the range of [GROSS ESTIMATES] some 30% to double that. The computed L/D for these configurations are in excess of 40 to much higher. The resultant fuel burn reductions are , without going to fuselage laminarization but using riblets for turbulent viscous drag reduction, in excess of 70% ..... Obviously as LENR energetics is developed, if it can be developed at the requisite power levels, the fuel fraction becomes seriously small and gross weight/ vortex hazard reduce further.

It should be noted that we have no detailed studies of truss braced wing truss optimization. The studies thus far have been at the systems not the detailed design level. We have never been here before. Obvious options include pre-stressing, hydraulic dynamic internal pressurization, laminar elements, arching, "Y" intersections with the wing to avoid supercritical flow regions, optimizing the overall number, nature, positioning of the elements, ETC. The truss could be carried out beyond the mid span/ wing hinge position, all of these options and far more are forward work.

Blended-Wing Body - At some level the major players (U.S., Europeans, Russians) are studying the technology for a jumbo aircraft in the 800+ PAX range which is, "different"--some variant of the spanloader or "blended wing body" (BWB). Jumbo options aside from conventional and BWB include multi-body and wing-in-ground (WIG) effect. The multi-body (double fuselage/ midwing discussed herein) is a viable candidate but the WIG is probably not. Study of the extensive Russian work in the WIG arena indicates several nontrivial problem areas for the WIG vis-a-vis the long haul transport mission - operation near the surface in high density air engendering a high drag level, structural and propulsive weight inefficiencies associated with water impact and takeoff thrust requirements and safety problems associated with operation at the extremely low altitudes required to attain appreciable ground effect benefits on "cruise" L/D.

The success of a "deployed version," the B-2 bomber, triggered interest, worldwide, in spanloader/ blended wing-body aircraft. The major performance benefits of such aircraft addresses the major issues for jumbo aircraft--noise and vortex hazard engendered by their great

weight. Obvious benefits of spanloader aircraft include large increases in L/D (due primarily to the demise of [much of the] fuselage wetted area/skin friction) and reduction in empty and gross takeoff weight. The design approach "puts the lift where the load is" for a requisite size aircraft with a physical wing thickness sufficient to allow passenger seating within the wing. The technological challenges (as well as the opportunities) of an 800+ PAX long haul BWB transport are tremendous but at least thus far evidently "workable." These challenges include thick wing sections (possibly with hybrid LFC and synergistic ("Goldschmied") propulsion integration), non-circular pressure vessels, stability and control, emergency passenger egress, airport compatibility and very high Reynolds number aerodynamics--both high lift and cruise. The BWB design inherently contains a major surfeit of internal volume and is therefore highly conducive to enhanced range, cargo operation and passenger comfort. In regard to the latter benefit, "sleeper" versions of the BWB could provide very interesting competition to SSTs for trans-Pacific routes in terms of enhanced comfort/lower price versus shorter transit time/cramped seating and higher price. The USAF "New World Vistas" study specifically called out the BWB approach as an excellent candidate to provide enhanced "global reach" airlift capability--in conjunction with precision (GPS-guided) delivery pallets as an alternative to the vehicle design decrements and vulnerability of landing "in theater." The large payload/volume and extraordinary range of BWB transports also provides capability for high capacity paratroop drops, cruise missile or UCAV carriage/launch, "AWACS" missions and "aerial replenishment."

Double Fuselage - Conventionally, double fuselage/multi-body aircraft have been employed to provide span-load distribution and accrue the associated structural weight benefits (reduced wing bending moment) without going all the way to a "blended wing body"/spanloader configuration i.e., providing such benefits via "conventional" (e.g., "comfortable") technology. Total aircraft drag is also reduced, primarily due to favorable effects on drag-due-to-lift.

An advanced double fuselage approach could attempt to delete the conventional outer wing panels and only retain a, largely unswept/long chord, wing section between the fuselages. This requires prodigious drag-due-to-lift reduction, a requirement which can be

addressed via design of the fuselages as wing-tip "end plates" and the individual fuselage empennage as "winglets," i.e., the tails become thrusting surfaces in the presence of the wing vorticity wrapping around the fuselage(s).

For this case, the "midwing" can become the site of the gear (to allow use of conventional runways), with engines "buried" at the rear of the fuselages to accrue the benefits of "boundary layer ingestion" and drag-due-to-lift reduction, with extensive (natural/ suction) laminar flow enabled by the largely unswept "midwing." Spanwise and localized ahead of the neutral curve heating strips in the wing leading edge region would enable, from theory and experiment, longer regions of laminar flow. The approach essentially converts the wing surface downstream of the neutral curve into a "cooled region" as far as the incoming [upstream heated] flow is concerned and for these speeds, in unswept flows, cooling is stabilizing. A major payoff would accrue from making the fuselages detachable/interchangeable to provide a civilian "sky-train" with enhanced productivity. The midwing portion which does all the "flying" could be in the air nearly "around the clock" with interchangeable freighter and/or passenger modules, thereby nearly doubling the productivity/ duty cycle and "return on investment." Such an approach would allow a restructuring of the airline capital investment, with the airlines "owning" their fuselages and leasing the "midwing" from a "rent-a-wing" company. Obviously, military versions could have cargo, troop, and refueling fuselages--providing a quantum jump in military flexibility and productivity.

PERSONAL AIRCRAFT- The "Converticar - The developed nations entered the 1900's with a transportation system (for people) centered upon the horse, the railroad and the steamship, with associated travel times the order of hours-to-days/weeks, depending upon distance. The automobile has long supplanted the horse and the fixed wing aircraft has nearly driven the railroads and steamship companies from the long haul passenger business. Travel times have shrunk to minutes-to-hours. These newer approaches have also had a profound influence upon the structure of modern societies. In the U.S., cities have expanded out of 18th century seaports and 19th century railheads, where much of the developed region was by necessity within walking distance of the transportation terminals, into tremendous automobile-enabled suburbs

with attendant reductions in crowding/increased opportunity for individual home ownership etc.

This section considers future possibilities/options for the non-transoceanic transportation spectrum, with emphasis upon the range from 10's to 100's of miles. The current dominant transportation mode for this mission is the automobile, which, possibly more than any other single technical achievement, has enabled the current life style enjoyed by the developed nations. In this process, the auto has created massive safety problems (order of 40,000 deaths/year in the U.S. due to highway accidents--which is the order of the U.S. casualty count for the entire Vietnam War) and has been responsible for the expenditure of truly prodigious sums on roads, bridges, pollution-induced health and material degradation remediation and the legal system. The current status of the auto infrastructure is that we continue to clear and pave more of the watershed, contributing to air pollution, flooding, desiccation, the formation of heat islands and wildlife habitat degradation. Also, the average trip time is increasing due to suburban expansion and increased congestion, causing non-trivial changes in family life as travelers attempt to utilize non-traditional time slots, or suffer long/nonproductive commutes.

Society cannot, easily or otherwise, continue to bear the costs imposed by almost sole reliance upon the automobile for short-to-intermediate passenger transport, alternatives are necessary for the future--both for the developed societies and those that desire to/are developing. Probably the most commonly advocated alternatives involve some form of mass transit, which have, along with tremendous capital costs, several other drawbacks such as passenger wait time, weather exposure and lack of privacy, security, pride of ownership and personal stowage. Additional drawbacks are the fact that they are not portal-to-portal and there is no guarantee of having a seat, as well as an inherent assumption and economic realism regarding required population density/concentration. Undoubtedly, the future mix of short-to-intermediate transport systems will include both mass transit and automobiles of some variety, probably operated on "intelligent" highways to improve safety and throughput/trip time.

There is, however, both a need and an emerging opportunity to include in the transportation mix a personal air vehicle which would provide, percentage-wise, the same increase in speed (compared to the auto in traffic), as the auto provided over the horse. Personal air

transportation usable by "everyone" is both revolutionary and the next logical step in the development of human infrastructure and corporal communication. The increased speed and potential safety improvements of such a capability, along with the greatly reduced capital requirements in terms of highways/bridges, etc., should allow significant increases in the quality of life as well as reduced state and national public works budgets. Specific benefits include distribution of the population over a much larger area allowing a more peaceful/less damaging co-existence of man and nature, along with improved transportation safety. The "vision" is of multilevel highways in the sky, controlled and monitored by inexpensive and reliable electronics and communications as opposed to narrow, single level, exceedingly expensive "ribbons of concrete." Such air systems/vehicles could also obviously be used for long(er) haul, as are automobiles today, e.g., travel of 500 miles or less is currently usually accomplished via auto. With a (faster) personal air vehicle this distance could be the order of 1500 miles or more. This in turn would have a major impact on domestic scheduled commercial air travel, 90 percent of which is over distances of 1500 miles or less. The various wait times associated with commercial air travel, along with the inefficiencies in terms of transit time of the hub and spoke system mitigate in favor of reduced overall trip time for slower, <u>but more direct</u>, travel via personal aircraft (compared to the "faster" commercial jet). Various options exist for personal aircraft systems. Certain requirements/desirements are common to any personal transportation vehicle/system. These include, besides affordability, short transit time/high speed, direct portal-to-portal, privacy and security, constant availability, personal stowage and a suitability for use by the "non-pilot." The latter necessitates from the outset that an obvious (and probably attainable) goal should be an <u>automatic</u> personal air transport system, automatic with respect to navigation, air traffic control and <u>operation</u>. The technology to accomplish this is either currently employed by/for the long haul air transport application, or in the research/application pipeline, thanks to the IT revolution and includes GPS, communication satellites and the military investments in RPV's, AAV's, UAV's, UTA's, UCAV's, MAV's, UAS etc. Such automatic operation could provide vastly improved safety, as the preponderance (70 percent to 80 percent) of air transport accidents have historically been due to "human error." In addition, it makes personal air vehicle transportation available to the general public, as

opposed to the few who have the opportunity, wealth, and physical characteristics/health to become pilots, as well as reducing the unit cost by an order of magnitude or more due to the concomitant vast increases in production rate/market.

To be competitive with the automobile a personal VTOL-converticar ['PAVE"] should have an acquisition cost in the vicinity of a quality automobile. Although in terms of the current main line helicopter industry, this is a ridiculous target, the advantages of a production run of millions instead of hundreds, along with the current offerings of a single seat helo for $30K and a two-place "gyroplane" for $20K, all at small production runs makes the outlook to achieve such a goal possible if not probable. All-weather operation is also a requirement, the same all-weather capability one now has in an automobile, which is by no means absolute. Extremely heavy rain, extreme winds, ice and snow will all either slow or stop the auto, and similar restrictions will probably hold for the personal PAVE vehicle. Obviously the evolving "detect and avoid" technology could be utilized (either on or off board) to increase safety vis-a-vis extreme weather.

Over the years, particularly since the 1930's, there have been suggestions, and in some cases strident calls, for the development and mass marketing of personal aircraft. Although "general aviation" has made considerable advances, the "aircraft for the masses" never really caught on for a variety of reasons, mainly involving COST, lack of requisite technology readiness and an absolute requirement that the "operator" be a "pilot," e.g., non-automatic operation. History is replete with examples of concepts which are good ideas and which keep resurfacing until the technology base or market is ready. Since the last personal aircraft campaign in the late 40's-50's, major strides have occurred in several enabling technologies. These include light weight, miniature, inexpensive and tremendously capable electronics/ computing (e.g., the IT revolution), lightweight composite materials with "nearly infinite" fatigue life, computational fluid mechanics, smart-to-brilliant materials/skins, flow control of several types and active controls/load alleviation. Such advances significantly change the personal aircraft discussion.

There are several "systems level" issues and critical choices regarding the personal aircraft which serve as key discriminators in the selection of a particular personal aircraft design. The first such issue is whether the personal aircraft (either "fixed" or rotary wing) should be a

separate air vehicle, or a "converticar," i.e., a combination automobile and air vehicle capable of economically performing both missions. Economics and utility strongly favor the "converticar" option. There are numerous elements common to both the air and ground vehicles, such as passenger compartments, engines, etc. and therefore, since it is technically feasible to reduce the weight of an auto to what is reasonable for an air vehicle, then a single vehicle should be considerably more economical in terms of initial cost and maintenance than buying and maintaining two separate vehicles. Simplex estimates of the flight-specific component weights indicate a value of less than 1000 [some indicate as little as 500] pounds, and therefore with shared utilization of common systems, the "all-up" weight of the converticar could be in the (reasonable) range of 3000 pounds or less. From an operational viewpoint a single vehicle should be much more convenient, obviating the need for a "rent-a-car" in the vicinity of one's destination. Once the converticar option is selected, some decision/recommendation has to be made regarding the provision for the "air-unique" components, particularly the lift-producing surfaces which require, for reasonable levels of drag-due-to-lift, non-trivial span/aspect ratio. Options include towed "trailored" wings (utilized in early versions of the converticar), fixed wings of inherently low aspect ratio for "roadability," airport "rent-a-wing" concessions where the wings are attached prior to, and removed at the conclusion of, flight, and telescoping/folding wings. The present author favors the telescoping/folding option as offering the best compromise between convenience and performance.

The next critical choice is between conventional/"fixed wing" operation and a rotary wing device. An essential difference is that the fixed wing machine/operation generally requires an airport except for powered lift approaches of various flavors. There are many thousands of GA airports and one would have to begin and end the air portion of the trip at one of these. In the opinion of the present author, this is simply too restrictive and contravenes several of the fundamental purposes of the personal air vehicle such as independence of/reduced requirement for large civil works, portal-to-portal transportation, and access to remote sites (remote from roads, etc.).

The Super STOL option would allow development/usage of currently undeveloped nations/regions at a fraction of the cost of the roads/bridges, etc. usually required for such development, and at much

less disruption to the environment. The estimated "off-shore" market for such a device is the order of $.5T/year with an eventual domestic (U.S.) market of the same order. Another major option involves the extent to which the operation in the air mode should be automatic as opposed to pilot/human derived. While sport models could be somewhat human-controlled (within the confines of the ATC/safety regulations) the optimal solution is clear. The portion of the population physiologically capable of becoming pilots is not large and there is considerable cost and time involved in doing so, most accidents are due to pilot error, and the ATC system requires, for the large numbers ultimately envisaged, automatic operation. Therefore, a user-orientated personal air capability should, ultimately, be automatic in operation as well as navigation and ATC, as already suggested herein. To avoid the "swarm" problem the vehicle would probably be constrained to operate in the ground vehicle mode in currently congested areas and only allowed to go airborne/automatic in low(er) population density areas unless are "Over-Flying". Eventually such a vehicle could change current land use patterns and allow reduced population density, with an effect on the current built-up suburbs similar to that of the automobile upon the central cities which, at least in the U.S., were largely bulldozed in the 50's to 80's following the auto-enabled population exodus.

Such an "automatic" super STOL machine would also provide, in an emerging world of IT-enabled increasingly prevalent tele-commuting and "electronic cottages," affordable/robotic delivery of requisite food supplies for the carbon-based inhabitants as well as goods ordered on the "net"/shopping channels.

Similarities between the horse-to-auto transition and potential auto-to- superSTOL converticar transition include occurrence in the early part of the century (~ 100 years apart), both provoke/enable major changes in land use/ecology, lead to atrophy of concentrated population centers, revolutionize the Nation's economy/builds upon Nation's technological strengths, and have an equivalent percentage increase in speed and personal action radius/elbow room/freedom of action/privacy. Differences between the two are favorable to the converticar, which should <u>enhance</u> safety and for which the infrastructure is largely in place. We do not have to clear and pave the watershed at prodigious cost (as required by the auto). The safety issue for the converticar can be approached via automatic operation and a

combination of vehicle parachutes and energy absorbing/crash worthy structural/material design.

It is not clear whether such a vehicle would make "sense," economically, technically and society-wise for those areas, such as parts of Europe, which are densely populated, and for that portion of the human race who prefer to live in crowded conditions. The IT Tele-Everything revolution appears to be removing much of the economic rationale for such population concentration. Particularly enticing Converticar markets include places with few intercity roads such as Island Nations [Indonesia, Malaysia], Siberia, Northern Canada, Parts of Africa and Alaska etc. These machines will and in fact ARE being developed because the technologies are now "ready", we can now "do this", for cost avoidance in terms of infrastructure, because the "tele-everything emerging lifestyle requires such connectivity [e.g. rapid, long distance robotic package delivery], the carnage on the roadways and increasing auto trip times and aggravation and the HUGE markets, extremely interesting "Business Cases". Congress in the U.S. has edicted access into the NAS for UAS. PAVE vehicles are simply UAS carrying PAX. One especially interesting SuperSTOL Pave vehicle approach is a channel wing with circulation control.

Pfenninger Extreme Arrow SST - Thus far SST's have not been particularly successful, either conceptually or in actual realizations. The Concord was a technological marvel for its' time but not commercially successful. Similar remarks hold for the TU-144. The basic SST issues are straight forward, the many and various Aeronautical Problems discussed early on in this report hold, but extended and confounded by the addition of serious wave drag , higher fuel fractions, higher temperatures, and greater weights, all driving up vehicle cost. Then there are the high altitude Ozone/ emissions problems, far more incident radiation, and the sonic boom, the latter causing anti-SST legislation. The sonic boom affects both people and things. There has been some success in reducing the "N-wave" peaks that affect people but reducing the low frequency "rumble" that affects buildings etc. is a much more difficult task. Lastly, there is the jet takeoff noise from the engines designed for propulsion at supersonic speeds. Taken together the various, in some instances rather extensive studies over the years since Concord of SST potential viability, especially economic viability,

have not been optimistic. There are concentrated studies ongoing of SST Business jets as such smaller vehicles both reduce the massive investment level required to field such machines and also reduce the sonic boom, which is first order dependant upon weight.

Advanced Configuration SSTs come in five major categories, unswept , thin natural laminar flow wings, parasol wing favorable interference, multi stage aircraft, yawed wings and the Pfenninger extreme arrow strut braced wing. The multi-stage approach usually involves a stage which includes the capability to get off the ground with acceptable noise/ high lift etc, and then separates/ returns to the airfield. The portion of the aircraft that lands at the end of the flight weighs far less, allowing carriage of lighter weight gear and high lift systems etc… In-Flight refueling is another multi-stage aircraft option. The yawed wing approach uniquely provides a low supersonic Mach number option that is nearly "boomless" and extremely efficient. Of these the Pfenninger extreme arrow strut braced wing appears to have the greatest SST potential, essentially doubling the Concord L/D of 7.3ish. The best NASA did in the HSCT/HSR program of the late 90's was an L/D in the range of 9.5. The Pfenninger designs proffer values in the range of 14 to 16 plus. The extreme arrow wing minimizes wave drag due to lift and wing wetted area as well as providing a credible span for vortex drag minimization. The short wing chord aids suction laminar flow control. There are mid-wing fuel canisters for favorable wave interaction and load alleviation with the possibility of natural laminar flow on the forward regions of the fuel cannisters and the fuselage. Several approaches utilized to optimize the truss braced CTOL design can also be applied to this SST including gear weight reductions via automatic landings and 'chutes for refused takeoff. This is particularly important in the SST case as the gear weight is the order of the fuselage weight. In addition, C-Wing tips would reduce DDL. The serious takeoff jet noise issue can be addressed via an essentially new approach – disabling/ reducing the causative turbulence dynamics vice reducing the jet velocity via entrainment using heavy "Mixer-Ejectors". Experiments and some theory indicates that the injection of liquid water jets, suitably tailored for effectiveness and minimal water mass flow can place water droplets in the mixing region of the external jet which reduce turbulence intensity and noise. The water injection produces additional thrust vice the mixer-ejectors that reduce thrust and is a way of "staging

the aircraft", the water is utilized during takeoff, does not have to be carried throughout the flight as does the mixer-ejector.

Having such a high L/D provides the margins necessary to address the myriad SST problems. As mentioned previously the "energy-rich conditions enabled by LENR, if/as it becomes viable could, via energy focusing well forward, greatly reduce sonic boom, as well as, obviously the fuel fraction/ attendant gross weight, which in turn further reduces sonic boom.

Probably "next-in-line" in terms of efficient SST configuration approaches would be the oblique/ yawed wing and recent work on a Bi-Directional Flying wing concept and the NASA N+3 SST studies. The former is due to R.T. Jones and is well discussed in the literature. The Bi-Directional approach is circa 2011 and involves a design based upon 90 degree rotation of the configuration for supersonic vice subsonic flight. The design thereby provides major alterations in aspect ratio for each speed range, enabling true bi-modal performance with excellent aero performance for both supersonic over water and subsonic over land. The overall approach is similar in philosophy to the variable sweep and yawed designs, but executed in a wholly novel fashion, with efficacy TBD. Such bi-modal aero performance improves the overall performance for the mission and reduces required fuel fraction.

Emerging Enabling Aeronautical Technological Approaches

As discussed in an earlier section of the present report, Society is currently undergoing a combined, simultaneous set of technology revolutions – IT, Bio, Nano, Energetics, Quantum. These are all occurring at the frontiers of the small and are often in a synergistic "feeding Frenzy". This section of the report addresses the opportunities these tech revolutions, and some associated creative thinking, can engender for several of the fundamental Aeronautical Technology Arenas – Aero/Propulsion interaction, Flow Control, Wave Drag Reduction and Drag due to Lift reduction. Also included under the general category of emerging Aero technologies are the breakthrough propulsion/ energetics opportunities. The possibilities associated with and the subject of LENR were previously discussed herein. Then there are the approaches, under study at various levels but not yet seriously applied,

to reinvent gas turbine engines. These approaches include serious regeneration, fostered by the NASA riblet technology to enable reductions in heat exchanger size/ weight, wave rotors, replacing the last compressor and first turbine stages and the combustor with dynamic processes and endothermic fuels/ fuel cooling. Overall, possibilities for an order of 50% better GTE.

Aero/Propulsion Synergies – Conventional design practice in civilian aeronautics is to essentially separate the aerodynamics and the propulsion system. The military, for over half a century has in many cases utilized synergistic combinations of Aero and Propulsion to obtain improved functionality, often for enhanced high lift performance. Such synergistic combinations are equivalent to approaching the overall Aero design problem in an open thermodynamic system where energy and mass/ species are added to the overall design space. Examples of such Aero/ propulsive synergisms include the following:

- Circulation Control Wings; produce up to a factor of 4 increase in Cl [to nearly the theoretical 4Pi maximum], reduced cost/ part count for "high lift" [possibly], improved control/ maneuverability including provision of ride quality if flight "in the weather" [below the Tropopause] is required to address the water emissions at altitude climate issue
- Boundary Layer Inlet; Ingesting lower momentum air, where the Fuselage/other Aero skin friction has already produced such enables greater propulsion efficiency [order of up to 10% to 15%]
- Wing Tip Engines; As discussed in the subsequent drag-due-to-left reduction section placing the engines on the wing tip can/ has for short span wings reduced drag-due-to-lift experimentally by up to 40%. The engine nacelle acts as an endplate, the engine energy and mass addition change to first order the dynamics of the wing tip vorticity rollup, also reduces wake vortex hazard. Wing strut and truss bracing are conducive to wing tip engine placement. A related Aero/ Propulsion interaction approach is wing tip injection using engine bleed air, which also reduces wake vortex hazard and drag-due-to-lift.
- Thrust Vectoring; Placing the engines at the rear of the fuselage and utilizing them for Aero Controls in lieu of the weight and drag of the empannage is a major performance enhancer.

- Goldschmied Thrusting Cowl; Goldschmieds' research indicated/ he suggested that placing a cowl around engines in the back, with boundary layer inlets, essentially puts potential flow "sinks" inside the body and increases the pressure on the back of the cowl, acquiring additional thrust in the process via Aero-Propulsion synergy. Research is underway to verify, or not, this assertion. The Submarine community, which utilizes such shrouded pump jets quite commonly, have accrued some additional performance benefits, the issues appear to be whether the benefits claimed by Goldschmied, up to some half of the fuselage friction drag, are obtainable. The boundary layer inlet propulsion improvements are the zeroth order effect / benefit of such a cowl.
- Hybrid Laminar Flow leading edge suction utilized for high lift separation control; This is a "twofer", the suction from the engine used for Hybrid wing Laminar flow at cruise for skin friction reduction utilized during takeoff for flow separation control/high lift.

Wave Drag Reduction - The "usual" (linear theory engendered) approaches to wave drag reduction (WDR) include wing sweep, area ruling and reduced thickness as well as wing twist/camber/warp. More recently Computational Fluid Dynamics (CFD)/nonlinear methods have been applied, resulting in further optimization(s). Classical non-linear WDR techniques include use of nose spikes (either physical or via forward projection of energy, gases, liquids or particulates) to extend effective body length – particularly useful on blunt nosed bodies , and base blunting which reduces the strength of the base recompression shock .

All of the WDR methods mentioned thus far involve weakening the shock. There is another whole class of approaches which utilize favorable shock interference. The fundamental approach is simplex in concept – utilize shock waves, via reflection/interaction, to create favorable interference either for body thrust or lift, or both. Generally volume distributions are utilized to synergistically create lift and lift distributions are utilized to cancel volume drag. Realizations of favorable interference include ring wings and the related parasol wings, multiple bodies (fuselages, control surfaces, wing pods) and propulsion

system interaction. For nonlifting bodies a ring wing can cancel, at design Mach Number, the volume wave drag of the body a la the "Busemann Biplane," at the expense of increased wetted area/weight etc. For the lifting case the Parasol wing provides both partial cancellation of the body/nacelle volume wave drag and an efficient lifting surface.

The application of favorable interference would be facilitated by flow separation control and active controls. Various experimental evaluations of favorable wave interference have resulted in far less than the expected inviscid performance levels due to the detuning and drag associated with flow separation caused by the concomitant shock wave-boundary layer interactions. The plethora of flow separation approaches currently extant, if employed at CRUISE conditions, should enable nearly inviscid performance levels. One such approach is use of passive porous surfaces. Flow separation control utilized during cruise could also greatly increase the percentage of lift carried on the upper surface as expansion waves-as opposed to the lower surface/(shock) wave rider conventional approach. The use of active flow control would allow both enhanced "on design" and improved "off design" performance via shock locus tailoring. As an order of magnitude estimate, parasol favorable interaction SST wings can provide order of 20 percent+ improvement in overall lift-to-drag ratio at cruise.

Drag-Due-to-Lift Reduction - Classical linearized theory indicates that elliptical loading, increased aspect ratio/span and lower lift coefficient values/reduced weight are the primary approaches to vortex drag due to lift reduction (DDLR). Obviously increasing aspect ratio/span beyond a certain point becomes inefficient overall due to structural penalties while decreased lift coefficient entails larger wings and both weight and wetted area/viscous drag increases. The application of the extensive alternative solution set for vortex DDLR has been relatively sparse (except for winglets) for many reasons including (depending upon the approach) structural weight, parasitic drag and/or power--addressable in many cases via creative overall aircraft configuration design - e.g. truss braced wings.

Relaxing the assumptions of classical linear theory (closed body, no energy addition, planar vortex sheet etc.) provides alternative vortex DDLR possibilities. In particular, use of non-planar lifting surfaces, e.g. distributing the lift vertically through various approaches such as upswept tips and multiple (vertically spaced) wings can provide sizable

reductions (up to order of 15 percent). Besides non-planar tips/span there are several interesting "natural" observations (morphology on Avians and Nektons) which may relate to DDLR including serrated trailing edges, leading edge bumps, shark caudal fin tips and sheared tips.

The vortex which forms at, and downstream of, the wing tip (caused by the tip upwash from the high pressures on the lower surface) affects a smaller percentage of the wing as aspect ratio increases. A characteristic feature of this vortex formation is flow which is at an angle to the free stream. Devices can therefore be inserted into this flow to produce/recover thrust and/or energy from this tip flow. This (simplistically) is the fundamental rationale behind at least four devices which reduce DDL. These devices can obviously also have an influence upon the vortex formation process itself and thus may directly influence DDL. These devices include tip turbines for energy extraction, winglets, vortex diffuser vanes, tip sails and a plethora of other tip devices such as wing grids, spheroid and c-tips. The vortex diffuser vane is supported by a spar behind the wing tip to allow the vortex to concentrate before interception. These devices work quite well, depending upon wing design and tip region loading and produce order of 5 to 15 percent reductions in DDL at CTOL conditions. Major application issues for these include, along with the "usual" concerns stated previously, possible utilization as control devices.

The following DDLR techniques are based upon either eliminating the tip altogether or adding mass (and /or energy) in the tip region. Eliminating the physical wing tips can be accomplished either via use of "ring wings" or joined wings and tails. Mass addition at/near the tip can be carried out either via tip blowing (local/remote passive or active bleed) or use of wingtip engines, resulting in sizable (up to 40 percent depending upon wing design) DDLR. Passive tip blowing could possibly be approached via wing leading edge ingestion (allowing increased wing thickness) with subsequent tip blowing used to tailor for the production of, and modulated to excite, virulent tip vortex instabilities at landing/takeoff to ameliorate the wake vortex hazard. Positioning the engines at the wingtip requires aerodynamic theoretical developments in an open thermodynamic system – as are adding energy/species as well as mass. Also, the engine nacelle can function as a "tip device".

There is an additional possibility for DDLR. Oscillatory span load distributions have been employed to reduce/obviate the wake vortex hazard. This same approach could well yield interesting levels of DDLR and should be investigated for such. Other design options that need

evaluation and possible optimization for DDLR include distributed propulsion and circulation control of front and rear wing stagnation points, the latter to investigate the possibility of rotating the lift vector into the thrust direction. The Truss braced wing as currently conceived reduces DDL some 75% by the simplex expedient of doubling the span, enabled by the structural characteristics of the external truss, enabling a wholly new set of optimization parameters/ approaches. Additional DDLR concepts include formation flight and utilization of alternative sources of lift including buoyancy, and thrust vectoring. The latter begins to be efficacious at high supersonic speeds and is beneficial at hypersonic cruise. Buoyant lift typically replaces DDL with a huge increase in wetted area/ skin friction, producing an overall high drag with, due to the large sizes/ areas, undue sensitivity to “weather”.

Flow Control, AKA “Designer Fluid Mechanics” - Designer Fluid Mechanics subsumes a large number of flow control approaches and applications. These include Laminar Flow Control [“Natural”/ pressure gradient induced at low sweep, and Forced or controlled], Mixing Enhancement especially for Propulsion systems components [e.g. combustor, exhaust jets], Separated flow control [especially for high lift, inlets, shock/boundary layer interactions], Vortex Control [wake vortex hazard , Super-maneuverability], Turbulence Control [Drag Reduction, mixing/ combustion, sensors], Favorable Wave Interference [Drag Reduction] and “Designer Fluids for internal systems. Flow Control at cruise to allow “Inviscid” performance optimization, smart controllers for load alleviation and trim drag reduction along with residual drag cleanup require additional study and optimization.

A vast number of flow control methods are available/ have been tried and sometimes applied. These include suction, injection, various body forces, surface motion[s], localized energy release, additives, surface permeability and heating/ cooling. Research in this arena has for some 2 decades been moving from passive control approaches to first active and then reactive. Due to systems/ applications considerations by far the bulk of the flow control applications have been passive devices. The now decades long development of smart, multi-functional materials might alter this conventional propensity toward passive flow control for applications.

Considering Laminar Flow Control, this has been under active research since the 1930‘s with most applications thus far being of the pressure gradient/ “Natural” Laminar Flow variety at relatively low Chord Reynolds

Number on GA aircraft. Until the 1960's LFC was bedeviled by issues of insect remains and other roughness and waviness. As improved materials and approaches mitigated these concerns it was the relatively low fuel cost that prevented LFC from "buying its' way" onto the aircraft in spite of numerous research flight experiments demonstrating feasibility/ performance. With the advent of "Peak Oil"/ increasing fuel costs and environmental concerns LFC is again under active consideration.

Another issue which has beset/ delayed the adoption/ utilization of some flow control devices has been facility capability shortfalls. In particular, except for NTF/ETW a lack of Reynolds Number to simulate the Wake Vortex Hazard has hampered the further development of devices/ approaches to mitigate such. The dissipation in the low Reynolds Number typical facility case causes quite different vortex behavior/ decay than in the high Reynolds number flight case. Also, the lack of low disturbance transonic facilities has been a problem not yet overcome for "certification" of LFC systems.

For [especially fuselage] turbulent drag reduction, a critical flow control arena once DDL and wing friction drag is minimized via LFC, the options, aside from relaminarization, are few currently. Obviously shorter and fatter [without incurring wave drag] reduces wetted area. Riblets have been flight tested and can provide some ~8% reduction. For air flows, unlike water where bubbles and trace amounts of long chain polymers provide large reductions, decreasing turbulent skin friction a sizable amount is uphill both ways. Perhaps the best opportunity might be to attempt to somehow operationize the research observations that oscillatory transverse wall motions can reduce turbulent viscous drag in air flow up to the order of 45%. There are current no widely known approaches to producing such wall motions that make sense in the real world of applied technology, but not all possibilities have been studied well. Analysis of the nose extensions on bill fish suggest that they produce a turbulent flow at low Reynolds number with/ on low wetted area, thereby shifting the CD-Re number curve to a lower drag condition over the main body of the fish with its' large wetted area. The potential benefit is not large but may be worth looking into for fuselage nose application.

Concluding Remarks

Civilian Aeronautics is currently in an “Interesting” period with a large number of increasingly serious problems and little current inclination to break out of the evolutionary product mode it has been in now for decades. The current product lines do not have sufficient “margin” to address these emerging problems in toto. It would appear necessary to work a shift in product lines to ensure success going forward. Prospective shifts include advanced configuration Aeronautics with factors, not percentages, improvements in margins/ performance and development of a wholly new line of business – the personal air vehicle. The ongoing exponential IT/Bio/Nano/Energetics/Quantum Technology Revolutions are both changing the “competition [especially in terms of non-physical “Virtual” travel] and enabling the advanced platforms and business lines required to meet those changes/competition issues/problems going forward. There is a nascent energetics technology, LENR, which may, by itself, completely revolutionize Civilian Aeronautics as well as just about everything else. Over 20 years of experiments indicating heat and transmutations with only sub EV inputs has established reality. We are now in the understanding and engineering phases, with results thereof TBD. Think fully electric wholly emissionless aircraft with negligible fuel fraction, MUCH less weight/vortex hazard, massively increased range, etc…..Energy density some 1,000 to 1,000,000 times chemical without the need for radiation protection weights. Structural nano tube dry weight reductions, again by factors not percentages, is yet another, but lesser, source of aeronautical revolutionary change.

The current Situation in Civilian Aeronautics is perhaps best typified by a quote from an NRC report “Aeronautics is not dead and buried, only sleeping”. It is past time for it to wake up.

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14. ABSTRACT

Paper address the major problems/issues with civilian aeronautics going forward, the contextual ongoing technology revolutions, the several emerging civilian aeronautical “Big Ideas” and associated enabling technological approaches. The ongoing IT Revolution is increasingly providing, as 5 senses virtual presence/reality becomes available, along with Nano/Molecular Manufacturing, virtual alternatives to Physical transportation for both people and goods. Paper examines the potential options available to aeronautics to maintain and perhaps grow “market share” in the context of this evolving competition. Many of these concepts are not new, but the emerging technology landscape is enhancing their viability and marketability. The concepts vary from the “interesting” to the truly revolutionary and all require considerable research. Paper considers the speed range from personal/general aviation to supersonic transports and technologies from energetics to fabrication.

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